APPENDIX E. MAINTENANCE

1. MAINTENANCE. All maintenance will be performed in accordance with FAR 43 and the manufacturer's instructions, or in accordance with a manual under an approved maintenance procedure. Records of maintenance should be entered in the airplane maintenance records required by FAR 43.9, or in the records required by the operator's approved maintenance procedures. Following repair or alteration, the system should be checked before predicating any operation on its use. Compatibility of the airborne area navigation system replacement components should be assured unless the replacement is of the same make and model as those upon which original approval was based.

2. INSPECTION AND TEST PROCEDURES. Operators using aircraft under IFR with an airborne area navigation system and not under an approved maintenance procedure should establish procedures which will be used to inspect and test the equipment periodically to determine that it is operating in accordance with at least the accuracy specified in Appendix A for minimum equipment. Such procedures should include a method for analyzing malfunctions and defects to determine that the established inspections and tests give reasonable assurance that the equipment is maintaining its accuracy. Test and inspection procedures and intervals should be adjusted in accordance with the results of the analysis.

APPENDIX F. AIR CARRIERS/AIR TAXI AND COMMERCIAL OPERATORS OF LARGE AIRCRAFT/TRAVEL CLUBS*

1. TRAINING PROGRAM. This type of operator should outline the training program he plans to set up to comply with the referenced FAR 121 parts. Under these rules, the training program is acceptable if:

   a. It encompasses all phases of the operation and fully covers all responsibilities of flight crewmembers, dispatchers and maintenance personnel.

   b. Its technical content for pilots covers:

      (1) Theory and procedures, limitations, detection of malfunctions, preflight and inflight testing, cross-checking methods, etc., relating to the operations; and,

      (2) An operational explanation of all systems, together with a review of navigation and flight planning.

   c. Its recurrent training program includes area navigation training.

   d. Each pilot assigned as an operating crewmember completes as many trips over a route or area (either in actual operation or, in part in an approved simulator or approved procedural trainer or training device) under the supervision of an appropriate instructor or a check airman, as may be necessary to:

      (1) Ensure his qualification in the system; and,

      (2) Enable certification of his proficiency in the system, as required by Section 121.401(c).

   e. The training program conforms with the above and is approved by a representative of the Administrator.

   *Travel Clubs will conform to the applicable parts of the above training program.

2. OPERATIONS MANUAL. Revisions to the operations manual should be provided outlining all procedures and emphasizing the methods for preflight and inflight test and step-by-step operation of the area navigation equipment. The manual should contain procedures for continuing the flight with partial or complete area navigation equipment failure.

3. MINIMUM EQUIPMENT LIST (MEL). For those components of the area navigation equipment required for area navigation operations, MEL revisions will be needed and operations specifications will so specify. The MEL should permit single system operation in dual system installations.

4. AUTHORIZATION. The operations specifications will contain the authorization to use an area navigation system and identify the airborne equipment.

5. APPROACH MINIMUMS. For the initial six months of RNAV operations, approach minimums may be approved with an additional margin of 200 feet and 1/2 mile above the MDA and visibility minimums published on the standard instrument approach procedure. At the end of that period, the minimums published on the standard instrument approach procedure may be approved on a permanent basis if the operational reliability has been satisfactorily demonstrated during the initial six month period.

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

OPERATIONS SPECIFICATIONS - EN ROUTE FLIGHT PROCEDURES

Form Approved
Budget Bureau No. 04-R083.1

ROUTE OR ROUTE SEGMENT	VIA	OPERATION AUTHORIZED				TYPE OF AIRCRAFT AUTHORIZED				SPECIAL REQUIREMENTS				
		DAY		NIGHT		DC-9 B-707				MOCA	MEA	MAA	OTHER	TYPE NAVIGATION[1]
		VFR	IFR	VFR	IFR									
							Note: Both pilots will be RNAV qualified in accordance with approved training programs, except that when navigation is being performed under the supervision of an approved RNAV-qualified check pilot, the pilots performing such supervised navigation need only have satisfactorily completed the approved RNAV ground school curriculum.							RNAV

EFFECTIVE DATE	NAME OF AIR CARRIER	
	ABC Airlines, Inc.	1 Where a navigator or special cockpit navigation and equipment is required, so specify; ie Navigator, Cockpit (Doppler - Loran), (Inertial). RNAV

FAA Form 8400-1 (10-68)

APPENDIX G. GENERAL AVIATION

1. TRAINING PROGRAM. The operator should become thoroughly familiar with the operation of his area navigation equipment before he uses this equipment in an IFR environment. A recommended training program should:

   a. Encompass all phases of the operation of the area navigation system.

   b. Cover the theory of operation, setting procedures, familiarization, detection of malfunctions, preflight and inflight testing and cross-checking methods.

   c. Include procedures for continuing the flight with partial or complete area navigation equipment failure.

   d. Provide that each operator of area navigation equipment will complete a sufficient number of simulated IFR approaches, missed approaches, departures and en route operations to ensure that he is competent to operate the equipment.

2. APPROACH MINIMUMS. The accuracy of RNAV equipment which meets only the minimum operational characteristics is such that a straight-in landing cannot always be assured. Therefore, general aviation pilots should not use lower than circling minimums unless they insure their RNAV systems are capable of consistently placing their aircraft within the final approach alignment tolerance.

   The lowest minimums that may be authorized for operations that meet the above performance are those published on the standard instrument approach procedure.

APPENDIX H. AIR TAXI

1. AIR TAXIS USING SMALL AIRCRAFT.

a. TRAINING PROGRAM. This type operator should outline the training program he plans to establish in compliance with the training requirements of his operations specifications. A training program is acceptable if:

(1) It encompasses all phases of the operation and fully covers all responsibilities of flight crewmembers and maintenance personnel.

(2) Its technical content, for pilots, covers:

(a) Theory and procedures, limitations, detection of malfunctions, preflight and inflight testing, cross-checking methods, etc., relating to the operation; and,

(b) An operational explanation of all systems, a review of navigation and flight planning.

(3) Its recurrent training program includes area navigation training.

(4) Each pilot assigned as an operating crewmember completes as many trips over a route or area (either in actual operation or, in part, in an approved simulator or approved procedural trainer or training device) under the supervision of an instructor or a check airman, as may be necessary to:

(a) Ensure his qualification in the system; and,

(b) Enable certification of his proficiency in the system, as required by Section 135.131.

b. OPERATIONS MANUAL. Revisions to the operations manual should be provided outlining all procedures and emphasizing the methods for preflight and inflight test and step-by-step operation of the area navigation equipment. The manual should contain procedures for continuing the flight navigation with partial or complete area navigation equipment failure.

c. AUTHORIZATION. The operations specifications will contain the authorization to use an area navigation system and identify the airborne equipment.

2. APPROACH MINIMUMS. For the initial six months of RNAV operations, approach minimums may be approved with an additional margin of 200 feet and 1/2 mile above the MDA and visibility minimums published on the standard instrument approach procedure. At the end of that period, the minimums published on the standard instrument approach procedure may be approved on a permanent basis if the operational reliability has been satisfactorily demonstrated during the intial six-month period.

APPENDIX I. COMPUTATION OF CROSS-TRACK AND ALONG-TRACK ERROR COMPONENTS.

1. TRACK ERROR.

The track error table is developed by combining the appropriate cross-track and along-track error vector derived from VOR, DME, RNAV equipment and pilotage error values. The value printed out in the table is the larger of the two possible vectors (left or right, fore or aft). The mathematics used in these computations for distance greater than five miles are shown in subsequent paragraphs.

NOTE: This appendix is presented for information purposes and for use by manufacturers who wish to develop tables for certification of equipment.

2. CROSS-TRACK.

a. Definitions.

D_1 = Distance from facility to the tangent point.

D_2 = Distance from aircraft to the tangent point.

D = Distance from facility to the aircraft.

θ = The angle formed by the tangent point, facility and the aircraft (facility at Vortex).

α = Ground VOR error.

β = Airborne VOR error.

γ = $\sqrt{\alpha^2 + \beta^2}$

DGE = DME ground error.

DAE = DME air error χ % or γ NM whichever is greater.

DTE = $\sqrt{DGE^2 + DAE^2}$

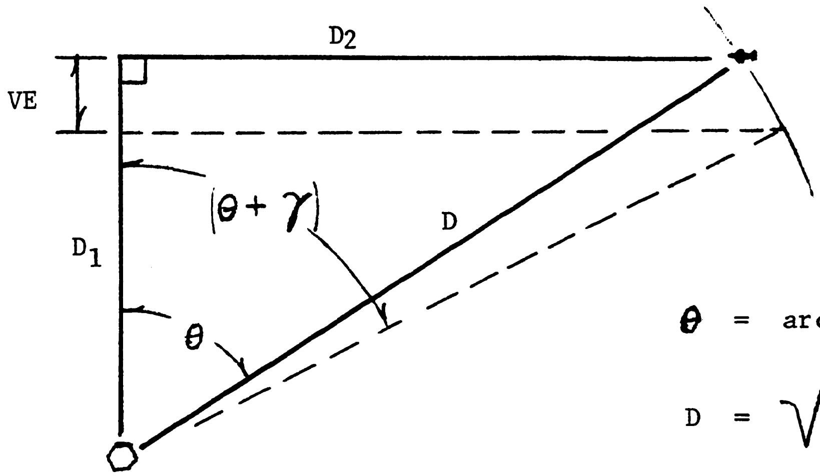
VE = Cross track component of errors due to α and β.

DE = Cross track component of errors due to DAE and DGE.

Pilot = Pilot error.

Comp. = Computer error.

b. VOR Component (VE)

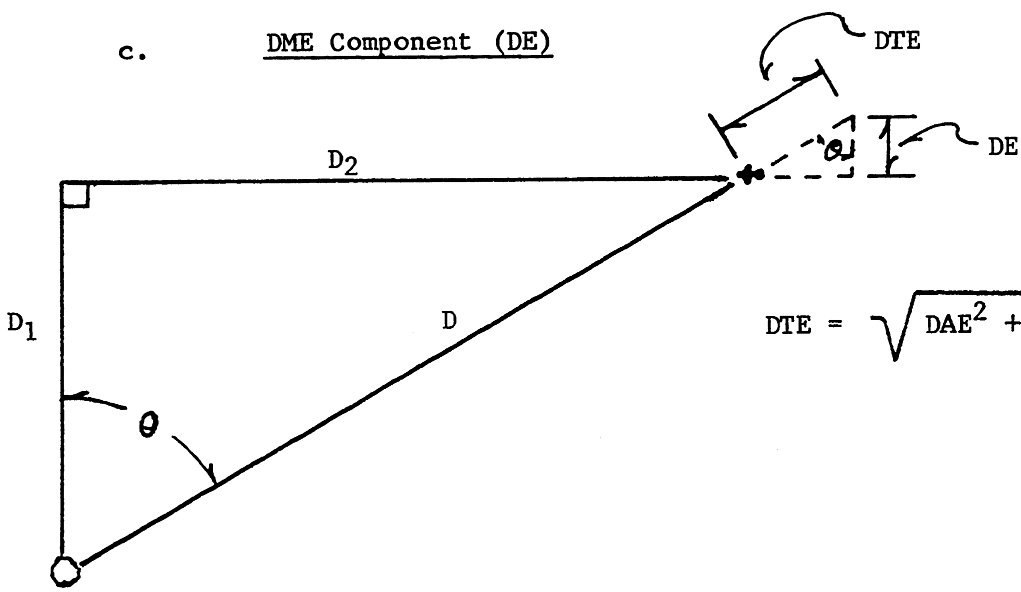


$$\theta = \arctan \frac{D_2}{D_1}$$

$$D = \sqrt{D_1^{\,2} + D_2^{\,2}}$$

$$VE = D_1 - D \cos(\theta + \gamma)$$

c. DME Component (DE)



$$DTE = \sqrt{DAE^2 + DGE^2}$$

$$DE = DTE \cos\theta$$

d. Total expected cross-track error (95%) probability

All cross-track components are combined by the "root-sum-square" method as follows:

$$\text{cross-track error} = \pm\sqrt{VE^2 + DE^2 + Comp^2 + Pilot^2}$$

3. ALONG-TRACK.

a. Definitions

D_1 = Distance from facility to tangent point.

D_2 = Distance from aircraft to the tangent point.

D = Distance from aircraft to the facility.

θ = The angle formed by the tangent point, facility and the aircraft (facility at Vortex).

α = Ground VOR error.

β = Airborne VOR error.

$\gamma = \sqrt{\alpha^2 + \beta^2}$

DGE = Ground DME error.

DAE = DME air error X % or Y NM whichever is greater.

$DTE = \sqrt{DGE^2 + DAE^2}$

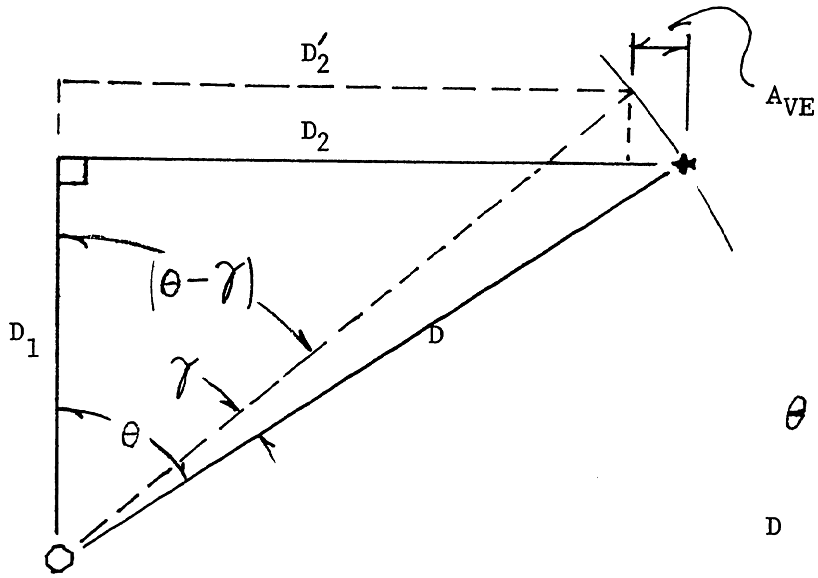
A_{VE} = Along-track component of errors due to α and β.

A_{DE} = Along-track component of errors due to DAE and DGE.

Pilot = Pilot error.

Comp. = Computer error.

b. VOR Component (A_{VE})



$$\theta = \arctan \frac{D_2}{D_1}$$

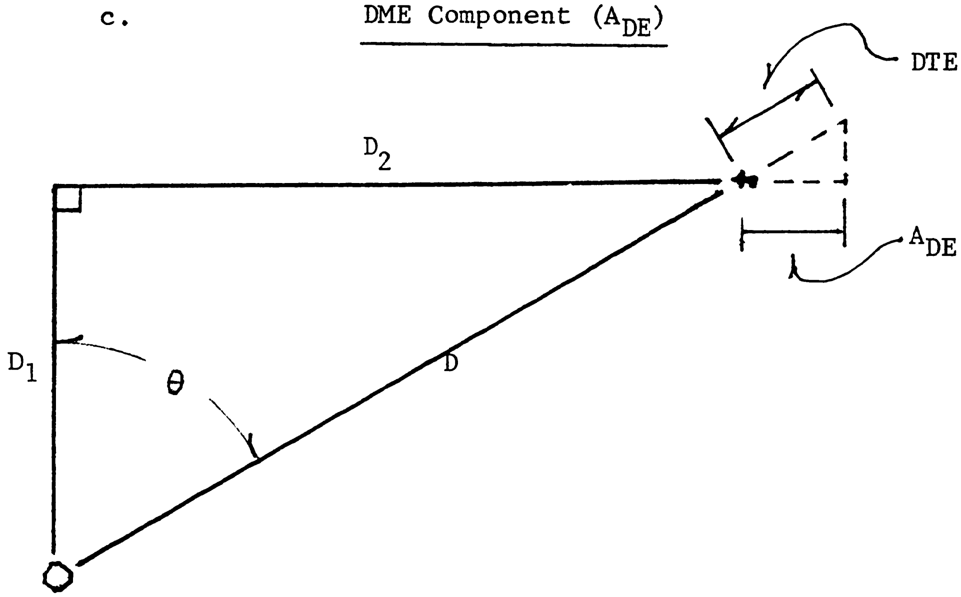
$$D = \sqrt{D_1^2 + D_2^2}$$

$$\frac{D_2'}{D} = \sin(\theta - \gamma)$$

$$D_2' = D \sin(\theta - \gamma)$$

$$A_{VE} = D_2 - D_2'$$

c. DME Component (A_{DE})



$$\text{Sin } \theta = \frac{A_{DE}}{DTE}$$

$$A_{DE} = DTE \text{ Sin } \theta$$

d. Total expected along-track error (95%) probability.

All along-track components are combined by the "root sum square" method.

$$\text{Along-track error} = \sqrt{A_{VE}^2 + A_{DE}^2 + \text{Comp}^2 + \text{Pilot}^2}$$

APPENDIX J. COMPUTATION OF GEODESIC INFORMATION

1. METHOD. Mathematical formulas used for geodetic computations are derived from a procedure developed by Sodano (U.S. Army Engineer; Geodesy, Intelligence and Mapping Research and Development Agency; Fort Belvoir, Virginia.) The method provides very good direct and inverse computational compatibility; it is used by the FAA for all Route development.

NOTE: This appendix is presented for information purposes and for use by manufacturers who wish to compare airborne computational processes. All angles are expressed in degrees and distances in Nautical Miles.

2. COMPUTATION OF A GEODESIC LINE GIVEN TWO GEODETIC POINTS.

Given: B_1, L_1 Geodesic Lat., Long. of P_1

B_2, L_2 Geodesic Lat., Long. of P_2

And

$F = 3.3901 \times 10^{-3}$

$A_o = 3443.95594$ (Semimajor Axis of the Earth)

Required:

A_{12}: Azimuth of Geodesic from P_1 to P_2

A_{21}: Azimuth of Geodesic from P_2 to P_1

S: Geodesic Length

Compute S (Geodesic Length in Nautical Miles):

$$S = (1-F)\, A_o\, S_1$$

Where:

$$S_1 = \Psi + \frac{(F^2 + F)}{2} \left[\Psi(2-M) + \alpha\,(2A-M\phi)\right]$$

$$+ \frac{F^2}{16\alpha} \left\{ 8\,\Psi^2\,(M-1)\left[A + \alpha \,\text{Cot}\, \frac{180\,\Psi}{\pi}\right] + \alpha^2\,\phi\left[8A\,(M\phi-A)+(1-2\phi^2)\right] + \alpha\,\Psi \right\}$$

$$\Psi = \frac{\pi}{180}\,\text{Arc Tan}\,\frac{\alpha}{\phi}$$

$$M = \frac{\alpha^2 - \text{Sin}^2 L\, \text{Cos}^2 \beta_1\, \text{Cos}^2 \beta_2}{\alpha^2}$$

$$\alpha = \left[\text{Sin}^2 L\,\text{Cos}^2\,\beta_2 + (\text{Sin}\,\beta_2\,\text{Cos}\,\beta_1 - \text{Sin}\,\beta_1\,\text{Cos}\,\beta_2\,\text{Cos}\,L)^2\right]^{1/2}$$

$$\phi = \text{Sin}\,\beta_1\,\text{Sin}\,\beta_2 + \text{Cos}\,\beta_1\,\text{Cos}\,\beta_2\,\text{Cos}\,L$$

$$L = \begin{cases} L' \text{ if } |L'| \leq 180^\circ \\ L' + 360\,\frac{|L'|}{L'} \text{ if } |L'| > 180^\circ \end{cases}$$

$$L' = L_1 - L_2$$

$$A = \text{Sin}\,\beta_1\,\text{Sin}\,\beta_2$$

$$\beta_i = \text{Arc Tan}\left[(1-F)\,\text{Tan}\,B_i\right] \text{ for } i = 1,\ 2$$

Compute A_{12} (Azimuth of Geodesic from P_1 to P_2)

$$A_{12} = \begin{cases} \sigma \text{ if } L \geq 0 \\ \sigma + 180^\circ \text{ if } L < 0 \end{cases}$$

Where:

$$\sigma = \begin{cases} \text{Arc Tan}\,\frac{a}{b} + 180^\circ \text{ if Arc Tan}\,\frac{a}{b} < 0 \\ \text{Arc Tan}\,\frac{a}{b} \qquad \text{if Arc Tan}\,\frac{a}{b} \geq 0 \end{cases}$$

$$a = \sin H \cos \beta_2$$

$$b = \sin \beta_2 \cos \beta_1 - \cos H \sin \beta_1 \cos \beta_2$$

$$H = \frac{180}{\pi} \left[\frac{\sin L \cos \beta_1 \cos \beta_2}{\alpha} \right] \left[x \right] + L$$

$$x = \Psi (F+F^2) - \frac{AF^2}{2\alpha} \left[\alpha^2 + 2 \Psi^2 \right] + \frac{MF^2}{4} \left[\alpha \phi - 5\Psi + 4\Psi^2 \cot \frac{180 \Psi}{\pi} \right]$$

Compute A_{21} in degrees (Azimuth P_2 to P_1)

$$A_{21} = \begin{cases} V & \text{if } L \leq 0 \\ V + 180^\circ & \text{if } L > 0 \end{cases}$$

Where:

$$V = \begin{cases} 180^\circ + \text{Arc Tan } \frac{c}{d} & \text{if Arc Tan } \frac{c}{d} < 0 \\ \text{Arc Tan } \frac{c}{d} & \text{if Arc Tan } \frac{c}{d} \geq 0 \end{cases}$$

$$c = \sin H \cos \beta_1$$

$$d = \sin \beta_2 \cos \beta_1 \cos H - \sin \beta_1 \cos \beta_2$$

Computation of the Geodetic Description of a True Bearing and Distance From A Given Geodetic Point.

Given: B_1 Geodesic Latitude of a P_1

L_1 Geodesic Longitude of a P_1

S Geodesic Length

A_{12} Azimuth of Geodesic from P_1 to P_2

And:

$F = 3.3901 \times 10^{-3}$

$A_o = 3443.95594$

Required: B_2 Geodesic Latitude of P_2

L_2 Geodesic Longitude of P_2

A_{21} Azimuth of Geodesic from P_2 to P_1

Compute B_2 Geodesic Latitude

$$B_2 = \text{Arc Tan}\left[\frac{\text{Tan}\,\beta_2}{1-F}\right]$$

Where:

$$\text{Tan}\,\beta_2 = \frac{\text{Sin}\,\beta_1 \,\text{Cos}\,\rho + \text{Cos}\,\beta_1\,\text{Cos}\,A_{12}\,\text{Sin}\,\rho}{\left[\text{Cos}^2\,\beta_o + (\text{Cos}\,\rho\,\text{Cos}\,\beta_1\,\text{Cos}\,A_{12} - \text{Sin}\,\beta_1\,\text{Sin}\,\rho)^2\right]^{1/2}}$$

$$\rho = r - \frac{90A_1E_2}{\pi}\,\text{Sin}\,r - \frac{M_1E_2}{8}\left(2r - \frac{180}{\pi}\,\text{Sin}\,2r\right) + \frac{225}{4\pi}\,A_1^2E_2^2\,\text{Sin}\,2r$$
$$+ \frac{M_1^2E_2^2}{128}\left[22r - \frac{2340}{\pi}\,\text{Sin}\,2r - 16r\,\text{Cos}^2\,r + \frac{1800}{\pi}\,\text{Cos}^2\,r\,\text{Sin}\,2r\right]$$
$$+ \frac{A_1M_1E_2^2}{16}\left[\frac{1080}{\pi}\,\text{Sin}\,r + 4r\,\text{Cos}\,r - \frac{900}{\pi}\,\text{Cos}\,r\,\text{Sin}\,2r\right]$$

$$A_1 = h\left[\text{Sin}^2\,\beta_1\,\text{Cos}\,r + \text{Cos}\,\beta_1\,\text{Cos}\,A_{12}\,\text{Sin}\,\beta_1\,\text{Sin}\,r\right]$$

$$r = \frac{180S}{\pi\,(1-F)A_o}$$

$$M_1 = h\ (1 - \cos^2 \beta_o)$$

$$h = 1 + \frac{E_2}{2} \sin^2 \beta_1$$

$$\beta_1 = \text{Arc Tan} \left[(1-F) \text{ Tan } B_1 \right]$$

$$\cos \beta_o = \cos \beta_1 \sin A_{12}$$

$$E_2 = (1-F)^{-2} - 1$$

Compute L_2 (Geodesic Longitude)

$$L_2 = \begin{cases} L_2' - \dfrac{360\ L_2'}{|L_2'|} & \text{if } |L_2'| > 180 \\ L_2' & \text{if } |L_2'| \leq 180 \end{cases}$$

$$L_2' = L_1 - V \cos \beta_o - L_c'$$

$$V = \frac{270\ A_1 F^2}{\pi} \sin r - Fr + \frac{3 M_1 F^2}{4} \left(r - \frac{90 \sin 2r}{\pi}\right)$$

$$L_c' = \begin{cases} L_c - 180 & \text{if } \sin \rho \geq 0 \text{ and } \sin A_{12} < 0 \\ L_c + 180 & \text{if } \sin \rho < 0 \text{ and } \sin A_{12} \geq 0 \\ L_c - 360 & \text{if } \sin \rho < 0 \text{ and } \sin A_{12} < 0 \\ L_c & \text{Otherwise} \end{cases}$$

$$L_c = \text{Arc Tan} \frac{\sin \rho \sin A_{12}}{\cos \beta_1 \cos \rho - \sin \beta_1 \sin \rho \cos A_{12}} \quad \text{where } -90 \leq L_c \leq 90$$

Compute <u>Geodesic Azimuth A_{21}</u> in degrees

$$A_{21} = \begin{cases} (A_{21}' + 180^\circ) & \text{if } \sin A_{12} \geq 0 \\ A_{21}' & \text{if } \sin A_{12} < 0 \end{cases}$$

$$A'_{21} = \begin{cases} \bar{A} + 180^\circ & \text{if } \frac{N}{D} < 0 \\ \bar{A} & \text{if } \frac{N}{D} \geq 0 \end{cases}$$

$\bar{A} = \text{Arc Tan } \frac{N}{D}$ where $-90^\circ \leq \bar{A} \leq 90^\circ$ (Principle Arc Tan)

$N = \text{Cos } \beta_o$

$D = \text{Cos } \beta_1 \text{ Cos } A_{12} \text{ Cos } \rho - \text{Sin } \beta_1 \text{ Sin } \rho$